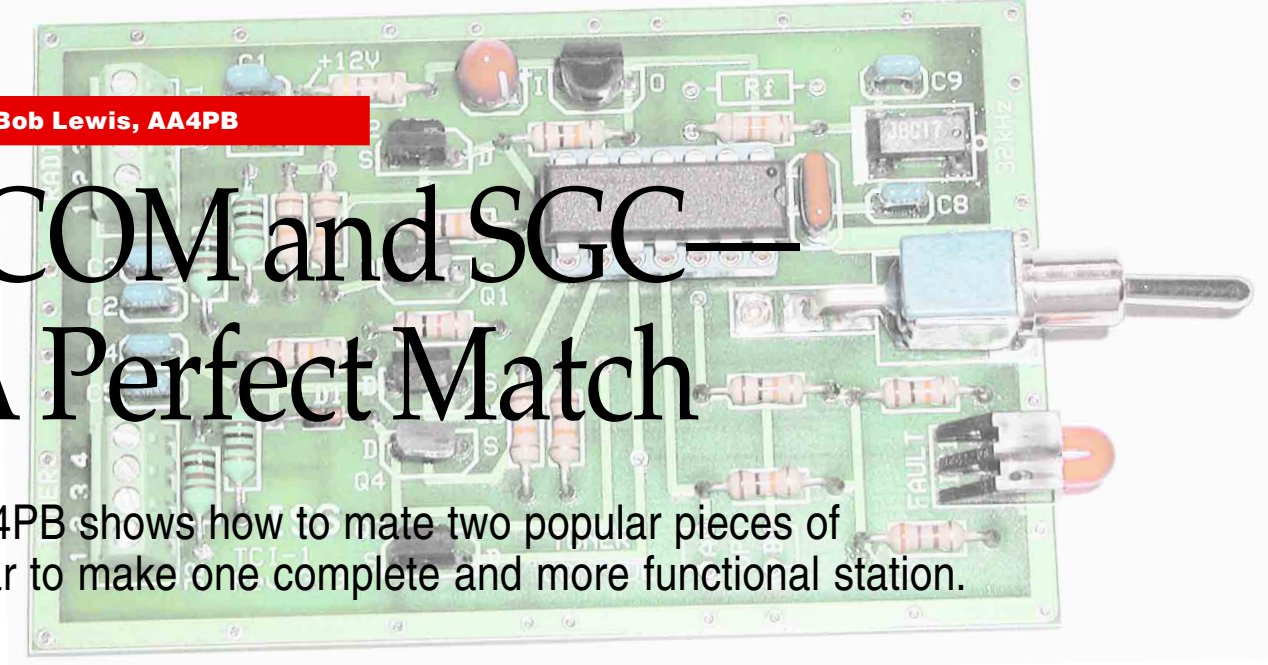
By Bob Lewis, AA4PB

ICOM and SGC—A Perfect Match



AA4PB shows how to mate two popular pieces of gear to make one complete and more functional station.

Having recently purchased an ICOM IC-706MKIIG for the mobile station, I decided to look into a better HF antenna for my pickup. I'd been through the Ham Stick and Hustler antennas, both of which worked fine but were rather inconvenient for changing bands or even moving around within a band. The various screwdriver type antennas are good performers but they are large and fairly difficult to mount on a pickup. In addition, tuning is slow and antenna removal for entering a garage or a drive-through was not very convenient.

The Problem

What I decided to try was a whip antenna with an automatic tuner located at the base. The ICOM AH-4 looked good because it could be controlled from the IC-706MKIIG front panel. The problem is that it is not designed to tune 75 meters with an 8 foot whip. The SGC SG-237, on the other hand, will tune 75 meters but it doesn't fully integrate with the '706. Yes, I know an 8 foot antenna on 75 meters isn't going to be very efficient, but it is better than nothing. For me, it represents an acceptable trade in exchange for the convenience. The SG-237 also retains all of the various frequency settings in non-volatile memory while the AH-4 loses all this information as soon as power is removed. Having these tuning solutions available means that the tuner may be able to find a match in well under a second if you have tuned on that frequency before. When this is combined with an interface that terminates the tune signal as soon as a match is found, you may only need to transmit a short "blip" of RF in order to get tuned up on frequency.

A Partial Solution

There are circuits available (one as simple as a single capacitor and resistor) that can cause the '706 to enter a tune mode and put out a 10 W carrier when its TUNE button is pressed. While this setup will certainly permit the SGC to tune, it lacks some very nice features of the AH-4. Using this method, the SGC will not notify the '706 that a match has been made, so the radio will continue to transmit the 10 W carrier until it has either timed out or the operator has pressed the TUNE button again to cancel it. Without this notification, the TUNE light on the radio could not properly display the status of the tuner (the light will normally be on if a match was found and off if the tuner was unable to find a match). The '706 could not reliably place the tuner in bypass (whip connected directly to the radio) in response to changing bands or a momentary press of the TUNE button. It has also been reported by a number of users that this circuit can occasionally cause the '706 to go into tune on its own when changing bands because the bypass pulse is misinterpreted as a TUNE command.

The Complete Solution

My solution was to build a small interface circuit that would connect between the '706 and the SG-237 tuner to provide the proper control signals for each. The schematic for this circuit is shown in Figure 1. I used a 14-pin PIC processor to provide all the timing and control functions. A 32 kHz tuning fork crystal divides down nicely to provide a 1 ms resolution for the PIC on-board timer. Timing is not critical but it needs to be reasonably stable because it is the pulse width that differentiates the various commands into and out of the radio's tuner interface.

One area of concern in this design was the potential for the PIC processor to generate RFI that would get into the '706 receiver. This is handled by ensuring that the processor is in sleep mode (with no oscillator running) except during the tuning process. RFI filters are placed on all of the inputs and outputs to help ensure that RF from the transmitter does not make its way into the processor circuitry.

The Tune Lock Feature

SGC tuners have a feature called *Tune Lock* that is generally implemented via their *SmartLock* accessory. Once the tuner has found a tuning solution, it can be locked so that it does not attempt a re-tune if the SWR changes momentarily as the whip moves around during vehicle motion. Ordinarily, one would have to manually flip the switch to unlock the tuner before it could respond to a band or frequency change. In this design, the PIC processor automatically overrides the *Tune Lock* switch setting when commanded to tune by the radio and then re-enables the setting when finished. If you prefer to have the tuner locked during normal operation, you can simply leave the switch in the LOCK position. When you press the TUNE button on the radio the tuner will unlock, retune the antenna and then lock the new settings.

I found a feature in the SG-237 that has not been documented in the SGC manual. If the *Tune Lock* switch is in the locked position when power is first applied or the tuner is reset, then the tune from memory feature is disabled until the power has been removed and reapplied. If the switch is in the normal position while power is applied, then the tune from memory feature works as expected. I worked around this problem by changing the PIC firmware to disable the tune lock until 100ms after power has been applied. This gives the tuner time to wake up and initialize before the lock function is asserted and permits you to

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leave the *Tune Lock* switch in the locked position at all times, even during power-up if desired.

Avoiding Multiple Resets

Rapidly switching the '706 through memory positions containing frequencies on different bands will cause the radio to output a series of tuner *reset/bypass* commands. This would occasionally cause the tuner to become confused and lock out the tune from memory feature. This is avoided by having the PIC firmware check the condition of the tuner before processing a reset command from the radio. The *reset/bypass* command is only sent to the tuner if it is in a tuned condition. Once the tuner has been placed in *bypass*, additional *reset* commands from the radio are ignored until the tuner has once again been tuned.

Planning for the Future

There are two jumpers (*Option A* and *Option B*) on the PC board that connect to two inputs on the PIC processor. These do nothing with the current version of PIC firmware. In the future these could be used to enable different features or possibly to select a different radio model if ICOM should decide to make some minor changes to the tuner interface.

How It All Works

Figure 1 shows the schematic of the interface. L1 through L5 and C1 through C5 form RFI filters for each lead entering or exiting the interface to ensure that internal circuits are not affected by RF from the transmitter.

When the '706 is first turned on it applies +12 V dc to pin 3 of the tuner interface connector. The radio then checks to see if +12 V dc is present at the STRT line (pin 2). If so, it assumes that a tuner is connected and activates that portion of the radio firmware that controls the tuner. If not, it assumes that a tuner is not connected and disables that portion of the firmware. Resistor R1 (10k) in the interface pulls the STRT line to +12 V dc in order to notify the radio that a tuner is connected.

The +12 V dc from the radio is used to power the tuner as well as being applied to the input of U1, which in turn supplies a regulated +5 V dc for the PIC processor. Resistor R3 and capacitor C6 provide an RC filter to keep any noise and spikes that may be on the vehicle power from reaching the regulator.

It is the STRT line (pin 2) that the radio uses to signal the tuner. The problem of course is that the SGC tuner doesn't understand the ICOM commands. The PIC processor translates those commands into something the SGC tuner does understand. A short low-level pulse (about 60 ms) on the STRT line means that the tuner should

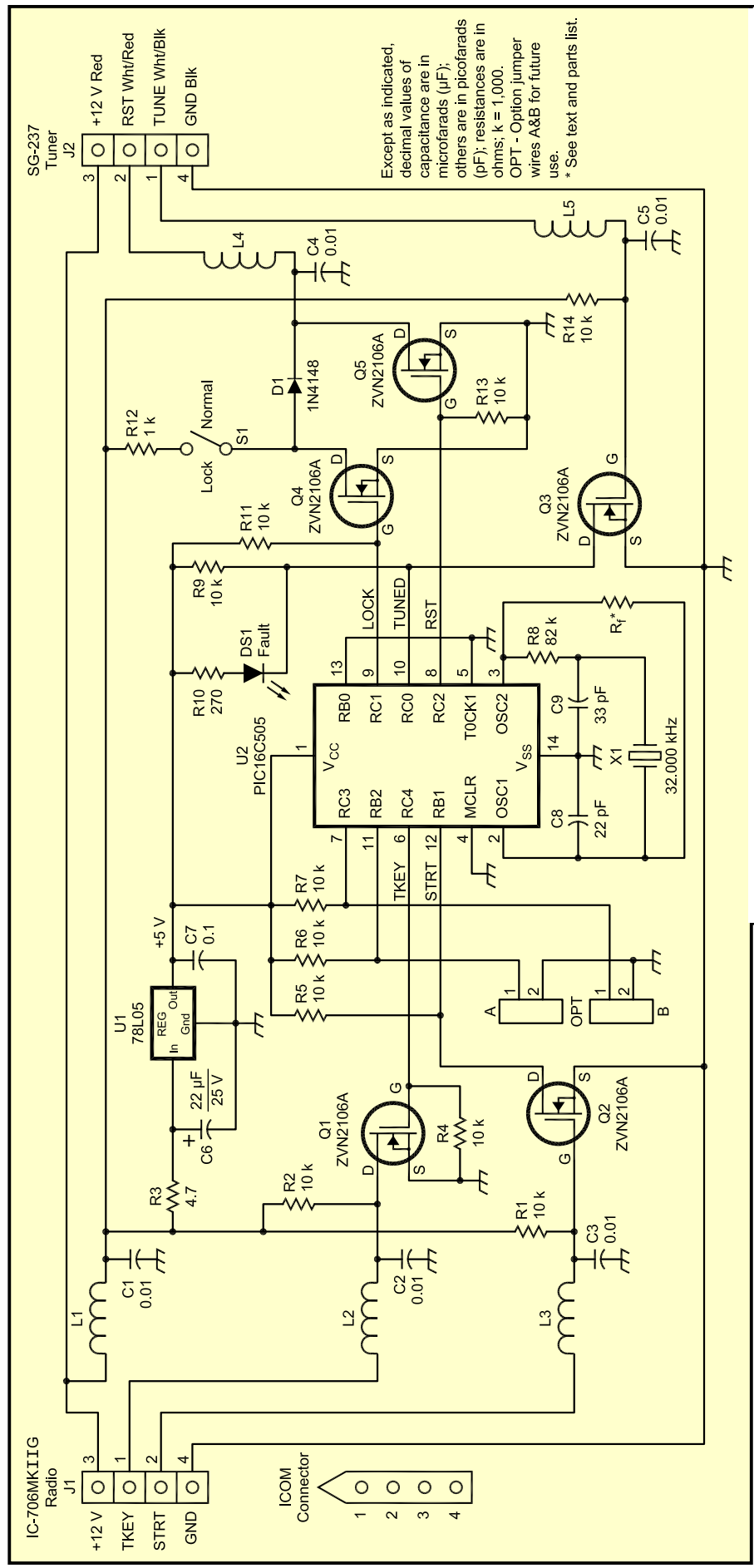

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Figure 1—Schematic of the PIC controlled SGC-ICOM interface. Parts are obtainable from DigiKey (701 Brooks Ave South, Thief River Falls, MN 56701; tel 800-344-4539; www.digikey.com) or Mouser Electronics (1000 N Main St, Mansfield, TX 76063; tel 800-346-6873; www.mouser.com).

C1-C5—0.01 µF, 50 V monolithic capacitor, DigiKey P4922-ND.
C6—22 µF, 25 V, tantalum capacitor, DigiKey, P2051-ND.
C7—0.1 µF, 50 V metal film capacitor, DigiKey, P4525-ND.
C8—22 pF, 100 V, 5% COG ceramic capacitor, DigiKey P4841-ND.
C9—33 pF, 100 V, 5% COG ceramic capacitor, DigiKey P4843-ND.
D1—1N4148 diode, DigiKey 1N4148FS-ND.
DS1—Red LED, right angle, PC mount, T-1.75, DigiKey L20011-ND.
J1, J2— Terminal block, Phoenix MPT-0.5/ 4-2.54, DigiKey 277-1275-ND.
L1-L5—100 µH, 125 mA inductor, J. W. Miller, DigiKey M7837-ND.
Q1-Q5—ZVN2106A or 2N7000, N-channel FET, TO92, DigiKey ZVN2106A-ND.
R1, R2, R4, R5, R6, R7, R9, R11, R13, R14—10 kΩ, ¼ W, 5% resistor, DigiKey 10KQBK-ND.
R3—4.7 Ω, 1/4 W, 5% resistor, DigiKey 4.7QBK-ND.
R8—82 kΩ, 1/4 W, 5% resistor, DigiKey 82KQBK-ND.
R10—270 Ω, 1/4 W, 5% resistor, DigiKey 270QBK-ND.
R12—1 kΩ, 1/4 W, 5% resistor, DigiKey 1.0KQBK-ND.
R_f—Typically 1 MΩ, 1/4 W, if needed for slow starting oscillator (see note).
S1—SPST, 2 pin right angle PC switch, Mountain Switch, Mouser or DigiKey 1055-TA1220 CKN1059-ND, SPDT RT Angle PC switch, C&K.
U1—78L05 regulator IC, 5 V dc, TO92, DigiKey NJM78L05A-ND.
U2—PIC16C505 µcontroller IC, UV erasable, DigiKey PIC16C505/JW-ND or PIC16C505 µcontroller IC, one-time programmable, DigiKey PIC16C505-04i/P-ND.
U2 socket—14 pin IC socket for U2, DigiKey A401-ND.
X1—Quartz crystal, 32.000 kHz, SMD, Citizen DS1 (see note) DigiKey 300-2007-1-ND.
ICOM connector—Molex 03-09-1041P connector, DigiKey WM1308-ND and Molex 02-09-2103 pins, DigiKey WM1100-ND.
Enclosure—Hammond 1455C801BK, Mouser 546-1455C801BK or DigiKey 1455C801BK-ND.
Rear panel grommets—Keystone, 5/16 inch mounting hole, Mouser 167-211.
Cable—8 inches, 4 cond, 22 gauge, stranded, 0.19 inch OD, Alpha 1174C, Mouser 602-1174C-100.

Notes

DigiKey XC488CT-ND 32.768 kHz crystal may be substituted with insignificant timing differences.

R_f is typically not needed unless there is a problem with slow startup of the oscillator after sleep mode.

The author has a limited number of PC boards and programmed PIC processor chips available for this project. The PC boards are double sided, plated through holes, solder masked and silk screened. The cost per set is $14 plus $1.50 shipping for delivery in the US and Canada. The shipping cost is $5 elsewhere. Orders can be accepted by mail or via PayPal at rlewis@midatlanticbb.com.

reset and enter the bypass mode, connecting the whip antenna directly to the radio. Bypass usually provides a better receive signal strength than going through a tuner set to the wrong frequency. It is therefore a good mode to be in until you are able to transmit the tune signal without causing interference to other stations. A long low-level pulse (about 500 ms) on the STRT line is the signal to begin tuning the antenna. The PIC processor monitors the STRT line while it is asleep and wakes up in response to any change.

As soon as the PIC processor detects a signal on the STRT line it immediately unlocks and resets the tuner into bypass mode. We want to enter bypass before tuning in order to force the tuner to find a new solution, even if it were already close. If the STRT line is released in a short time then tuning is not being requested and the PIC processor goes back to sleep, leaving the tuner in bypass. If the STRT line remains low for 500 ms then a tune is being requested. The PIC processor then pulls the radio's TKEY line low via Q1 in order to force the radio to emit a 10 W carrier for tuning. During this time the radio emits a tone from its speaker to notify the operator of the tuning operation.

Upon receiving the RF carrier, the first thing the SG-237 tuner does is to measure the frequency. It then checks to see if the frequency is listed in one of its memory bins. If so, it can simply reselect the appropriate L and C values from a look up table rather than going through the whole tuning process. Under these circumstances the antenna can be tuned in as little as 10 ms, according to the SGC manual. I find the total "on the air" time to be about 500 ms in most cases. This includes the tuning time plus delays in the radio and PIC interface. If the settings for this frequency are not available from a memory bin or the resulting SWR is greater than 2:1 then the tuner goes through its tuning algorithm in order to find a good match and then records those settings in a memory bin for future use. I find this generally takes between 2 and 5 seconds of total "on the air" time. Upon finding an appropriate match, the tuner pulls its TUNED line low signaling the PIC processor to unkey the TKEY line and terminate the carrier. This action results in a short transmit time in order to tune the antenna and minimizes interference.

If the tuner fails to find a match after trying all possible combinations of L and C, then it signals the PIC processor by pulsing the TUNED line. This was intended by SGC to flash the LED on their *SmartLock* device. The PIC processor also has a 30 second fail-safe timer to prevent the radio from remaining keyed if the tuner should fail. In either case a match is not found, so the PIC processor sends a 200 ms pulse to the radio's TKEY line to signal the radio to turn off its TUNE light. The operator then knows the antenna is not functioning properly.

DS1, the FAULT LED on the interface provides an additional indication of the tuner condition by lighting any time that the tuner is not properly tuned (meaning its TUNED line is high). This is inverted from SGC's normal method of providing a green light indicating that the tuner is properly tuned. My thinking is that the FAULT LED will not be on during normal operation so there is one less light source in the vehicle at night and the red light is more alerting to the operator in the event of a tuning problem.

Now lets take a closer look at how the lock and reset functions work. The RST line on the SGC tuner is three-state. Momentarily pulling it to ground puts the tuner in bypass. Pulling it high (toward +12 V dc) puts the tuner in lock. Letting it float puts the tuner in normal operation. If S1 is in the locked (closed) position then R12, through D1, pulls the RST line high (locked). If S1 is in the open position then R12 is not connected and the RST line floats (normal operation). If the PIC processor wants to unlock the tuner then it pulls the gate of Q4 high. Q4 in turn grounds the junction of R12 and D1 so that D1 is reversed biased and leaves the RST line floating (normal operation) even if S1 is closed. If the PIC processor outputs a high to the gate of Q5 then Q5 conducts, grounding the RST line (*reset* to *bypass* mode).

The 32 kHz crystal, X1, provides the processor clock and internal timer reference for the PIC processor. Resistor R_f is not normally needed. A place is provided for it on the PC board in the unlikely event that it is needed to increase the feedback to compensate for a slow starting crystal.

One of the critical issues in the development of any PIC circuit is to ensure the proper drive level to the crystal. Low frequency tuning fork crystals require very

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little drive. Too much drive can cause the crystal to fracture and fail after a matter of weeks or months. Too little drive may cause the oscillator to fail to start under conditions of temperature extremes. The goal is to provide as high a drive level as possible without distorting the oscillator waveform on pin 3 of the PIC (U2). The value shown for resistor R8 was selected experimentally to provide the proper drive level and should work fine for the majority of crystals.

Capacitors C8 and C9 were selected to provide the specified load capacitance to get the crystal on frequency. Making C9 slightly larger than C8 assists the oscillator in starting when power is first applied to the PIC.

Operator Controls

Two operator controls are used to control the tuner; The LOCK switch on the interface and the TUNE button on the radio.

LOCK Switch

The only operator control on the interface is the LOCK switch. Leave it in the LOCK position if you do not want the tuner to respond to changing SWR. Put it in the NORMAL position if you want the tuner to retune automatically any time the SWR goes above 2:1 while you are on the air.

TUNE Button

If the tuner is properly tuned, the red LED on the '706's TUNE button is illuminated and a momentarily press of the TUNE button will place the tuner in bypass. If the tuner is already in bypass, the TUNE button is not illuminated and a momentary press will begin the tuning process. The tuner is also placed in *bypass* any time the band is changed on the '706.

If the tuner is already tuned, you can press and hold the TUNE button for about 2 seconds in order to place the tuner in *bypass* and immediately begin retuning.

During a tuning process you can press the TUNE button to cancel the tuning operation. The radio will immediately stop transmitting, the tuner will be placed in *bypass*, and the PIC processor will cancel all timing operations and go back to sleep.

Operating the Tuner-Transceiver Interface

Forcing a Complete Retune

If the tuner is properly tuned, then placed in *bypass*, and then tuned again on the same frequency it will assume that you were not satisfied with the SWR previously obtained from the memory settings. In this case the tuner will go through a complete retuning process to obtain the lowest possible SWR and load these new settings into its memory bin for that frequency. You might want to do this if the antenna conditions had changed a little and the settings loaded from the memory bin resulted in an SWR of 1.9:1, for example. It is not 2:1 so the tuner will not automatically search for a new solution but you may not want to operate at a 1.9:1 SWR, so you force a retune.

Radio Settings

Always set the radio menu item 27, A-TUNE STRT, in the (default) OFF position. If you want the tuner to automatically retune in response to a high SWR then use the LOCK switch on the interface instead of the A-TUNE STRT function on the radio.

If you want the radio to automatically request retuning at the first microphone PTT press after the frequency has been changed by at least 1 percent, set radio menu item 28, PTT TUNE, to the ON position. It is set to OFF by default. Personally, I find this to be a very convenient function.

PIC Programming

The code for the PIC processor was written in assembly language. I used the Microchip *MPLAB* assembler available for free download from their Web page at **www.microchip.com** to develop the code. I used the *P16PRO40* programmer board kit and *picallw.exe* software available from Amazon Electronics at **www.electronics123.com** to program the PIC. The complete hex and object code, along with a software flow chart, can be found at **www.arrl.org/files/qst-binaries/ICOM-SGC interface.zip**.

A pre-programmed PIC chip and a double-sided PC board with plated-through holes, solder mask and silkscreen is available from the author. See the end of the parts list of Figure 1.

Construction

All of the components for this project, except for the PC board, are stock items available from DigiKey and Mouser Electronics.

The interface is constructed on a 2× 3.15 inch double-sided PCB with plated through holes. The PCB slides into an extruded aluminum case measuring 2.126 wide × 3.15 long × 0.908 inches high. Two 4 pin, PC mounted terminal blocks are used to attach the wires from the radio and the tuner. It is highly recommended that the PIC processor (U2) be mounted in a good quality 14 pin IC socket in order to make its replacement easy. This chip contains the program memory and its replacement will allow you to upgrade the firmware in the future.

All of the components are standard through-hole devices except for the crystal (X1). The crystal is a 4-terminal surface mount device (SMD) selected for its good mechanical reliability in a mobile environment. It is important that the crystal be the first component installed on the PC board and that it be properly oriented. Soldering this device in place with other components mounted around it will be difficult. Removing it without destroying it will also be quite difficult so it is best to get it right the first time.

It is important that the FETs be installed with the proper orientation. They are not likely to survive the first application of power if they have been installed in the

Figure 2—SG-237 antenna tuner mounted inside the pickup truck bed, showing the antenna base and the homebrew Delrin insulator.

circuit backward. A magnifying glass can be a big help in determining which side of these devices is the flat side.

A Word about Whip Mounting

A short mobile whip antenna can develop some very high voltages at the base, especially at the lower frequencies. With 100 W, it would not be unusual to have 1000 V or more at the base at 3.5 MHz. SGC warns that the typical CB-type ball mount could arc over. The typical $^3/_8$ inch stud mount with nylon shoulder washers will certainly not stand up to these voltages, especially when wet or covered with road dirt.

My solution was to machine a piece of 1.5 inch diameter × 3 inch long Dupont *Delrin* rod. I have a 1 inch deep, $^3/_8$×24 hole threaded in each end. This leaves 1 inch of Delrin between the ends of the mounting bolts to provide insulation. The Delrin insulator serves to insulate the whip from the mount. The feed wire is connected to the base of the antenna at the top of the insulator so that no voltage is present on the mount.

Since I have a pickup, I purchased a very substantial stake pocket mount from GeoTool (**www.geotool.com/antmount.htm**) to provide a solid support for the custom insulator.

There are two key points to note about any mobile tuner/whip installation. One is to provide a very good RF ground connection between the tuner and the vehicle. The other is to use as short a feed line as possible between the base of the whip and the tuner. This wire must not be coax cable

Figure 3—The tuner installation showing the homebrew Kydex protective cover in place.

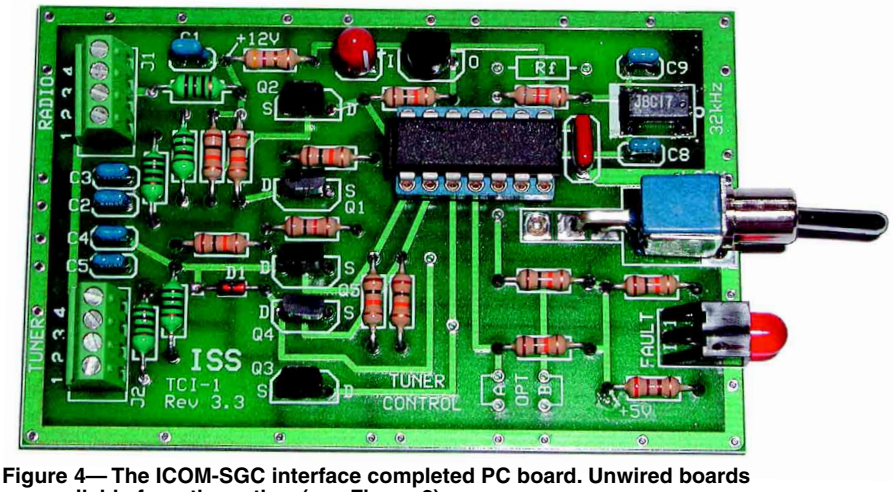

Figure 4— The ICOM-SGC interface completed PC board. Unwired boards are available from the author (see Figure 2).

and it must be kept as far away as possible from any metal or other conductive surface. In this case, the feed line is part of the antenna and it is operating at high impedance (perhaps 2 kΩ or more) on the lower frequencies.

Figure 2 shows the completed SG-237 and antenna installation. Note the Hustler QD-2 quick disconnect between the top of the Delrin insulator and the base of the SG-307 whip antenna. The connecting feed wire is the center conductor removed from a piece of RG-8 coaxial cable and covered with black heat-shrink tubing. All of the mounting hardware is stainless steel purchased from a local Boater's World store. I made extensive use of exterior tooth star washers that bite into the metal, even through paint, to make a good electrical connection. Behind the mounting plate, a 1 inch wide tinned braid runs down to make a good connection to the vehicle chassis as well as the bed of the pickup.

Even though the SG-237 is waterproof, SGC recommends that some type of cover be provided to prevent direct exposure to sunlight and rain. Figure 3 shows the homebrew Kydex cover that provides the added protection. Note that the cover is painted a light color to minimize heat buildup.

There has been some talk going around the Internet recently that a 102 inch stainless steel whip will not work on 75 meters and that a Ham Stick or similar type center loaded whip should be used with the tuner. I have conducted on the air tests that show absolutely no advantage to using a Ham Stick over the 102 inch whip on 75 meters with a properly installed SG-237 tuner. This tuner and a 102 inch whip will cover 80/75 meters through 6 meters quite well without using any additional loading coils.

Use with Other Radios and Tuners

I anticipate that the interface will work fine with any ICOM transceiver that is designed to interface with the ICOM AH-4 tuner. It should work with any SGC tuner model that has a TUNED indicator output that is pulled to ground to indicate a tuned condition and a combined LOCK/HOLD/RESET line. Looking at the schematics for the current SGC line, I expect that it will work with the SG-230 and the SG-239 as well as the SG-237. It will *not* work with the SG-231 or SG-235 as these models have separate LOCK/HOLD and RESET lines. I caution that I have only tested the interface with the ICOM '706 transceiver and the SG-237 tuner. My assumption that it will work with the SG-230 and SG-239 tuners is based on an inspection of their schematics that revealed that these tuners have the same internal interface hardware as the SG-237.

Conclusion

With the described interface and mobile setup, changing bands or frequencies within a band is very quick and easy. With PTT TUNE set to on, tuning is as simple as a quick push of the microphone PTT button. Tuning is fully automatic so you get to keep your eyes on the road where they belong. Because tuning is so fast and automatic, the potential for interference is minimized.

Bob Lewis, AA4PB, has been interested in Amateur Radio since his junior high school days in the late 1950s. His first call was K8KNI and he operated 6 meter AM in the Detroit area during those early days. His interest in radio led to a career in electronics as an air-transport radio mechanic and 10 years in the Navy as an aviation electronics technician. Bob has an Amateur Extra class license and enjoys low-power operation, the digital modes and homebrewing. He's retired from Civil Service and currently works part time in electronics consulting. You can contact him at PO Box 522, Garrisonville, VA 22463; **rlewis@midatlanticbb.com**. QST

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